CLAIMS

What is claimed is:

1. A droplet ejection apparatus comprising:

a plurality of droplet ejection heads, each of the droplet ejection heads including:

a diaphragm;

an actuator which displaces the diaphragm;

a cavity filled with a liquid, an internal pressure of the cavity being increased and decreased in response to displacement of the diaphragm; and

a nozzle communicated with the cavity, through which the liquid in the cavity is ejected in the form of droplets in response to the increase and decrease of the internal pressure of the cavity;

a driving circuit which drives the actuator of each of the droplet ejection heads;

ejection selecting means for selecting the droplet ejection head in the plurality of droplet ejection heads through the nozzle of which a droplet is to be ejected;

ejection failure detecting means for detecting a residual vibration of the diaphragm in the droplet ejection head selected by the ejection selecting means and detecting an ejection failure of droplets on the basis of a vibration pattern of the detected residual vibration of the diaphragm; and

switching means for switching a connection of the actuator from the driving circuit to the ejection failure detecting means after carrying out a droplet ejection operation by driving the actuator.

2. The droplet ejection apparatus as claimed in claim 1, wherein the droplet ejection apparatus is adapted to sequentially carry out the detection of the ejection failure of the droplets for the plurality of droplet ejection heads one by one.

3. A droplet ejection apparatus comprising:

a plurality of droplet ejection heads, each of the droplet ejection heads including:

a diaphragm;

an actuator which displaces the diaphragm;

a cavity filled with a liquid, an internal pressure of the cavity being increased and decreased in response to displacement of the diaphragm; and

a nozzle communicated with the cavity, through which the liquid in the cavity is ejected in the form of droplets in response to the increase and decrease of the internal pressure of the cavity;

a driving circuit which drives the actuator of each of the droplet ejection heads;

ejection selecting means for selecting the droplet ejection head or droplet ejection heads in the plurality of droplet ejection heads through the nozzle of each of which a droplet is to be ejected;

a plurality of ejection failure detecting means for detecting a residual vibration of the diaphragm in each of the droplet ejection heads selected by the ejection selecting means and detecting an ejection failure of the droplets on the basis of a vibration pattern of the detected residual vibration of the diaphragm in each of the droplet ejection heads; and

a plurality of switching means which, after carrying out droplet ejection operations by driving the actuators corresponding to the selected droplet ejection heads, respectively switch connections of the driven actuators from the driving circuit to the plurality of ejection failure detecting means corresponding to the driven actuators.

4. The droplet ejection apparatus as claimed in claim 3, wherein the droplet ejection apparatus is adapted to carry out the detection of the ejection failure of the droplets for each of the plurality of droplet ejection heads substantially

simultaneously.

5. The droplet ejection apparatus as claimed in claim 3, wherein each of the plurality of switching means carries out the switching operation in response to a predetermined switching signal.

6. The droplet ejection apparatus as claimed in claim 5, further comprising switching control means for controlling the switching means that corresponds to the droplet ejection head selected by the ejection selecting means to carry out the switching operation.

7. The droplet ejection apparatus as claimed in claim 6, wherein the switching control means comprises a plurality of AND circuits that respectively correspond to the plurality of switching means and are placed between the ejection selecting means and the respective switching means.

8. A droplet ejection apparatus comprising:

a plurality of droplet ejection heads, each of the droplet ejection heads including:

a diaphragm;

an actuator which displaces the diaphragm;

a cavity filled with a liquid, an internal pressure of the cavity being increased and decreased in response to displacement of the diaphragm; and

a nozzle communicated with the cavity, through which the liquid in the cavity is ejected in the form of droplets in response to the increase and decrease of the internal pressure of the cavity;

a driving circuit which drives the actuator of each droplet ejection head;

ejection selecting means for selecting the nozzle of the droplet ejection head in the plurality of droplet ejection heads from which a droplet is to be ejected;

detection determining means that determines for which nozzle of the droplet ejection head an ejection failure of the droplets is to be detected;

ejection failure detecting means for detecting a residual vibration of the diaphragm in the droplet ejection head determined by the detection determining means and detecting the ejection failure of the droplets on the basis of a vibration pattern of the detected residual vibration of the diaphragm; and

a plurality of switching means respectively corresponding to the plurality of droplet ejection heads, wherein, after carrying out a droplet ejection operation by driving the actuator corresponding to the nozzle of the droplet ejection head determined by the detection determining means, the switching means corresponding to the determined droplet ejection head switches a connection of the driven actuator in the determined droplet ejection head from the driving circuit to the ejection failure detecting means.

9. The droplet ejection apparatus as claimed in claim 8, wherein the detection determining means includes:

switching selection means for selecting the switching means corresponding to any one of the plurality of droplet ejection heads to carry out the switching operation; and

switching control means for controlling the switching means corresponding to the droplet ejection head selected by the switching selection means and the ejection selecting means to carry out the switching operation;

wherein, when the switching means corresponding to the droplet ejection head determined by the detection determining means is switched by the switching control means to carry out the switching operation, the ejection failure detecting means detects the ejection failure in the determined droplet ejection head.

10. The droplet ejection apparatus as claimed in claim 8,

wherein the detection determining means repeatedly carries out a scanning operation in which any one of the plurality of switching means is sequentially scanned in a predetermined order, and determines the droplet ejection head when the timing of the droplet ejection operation of the droplet ejection head coincides with the timing of the scanning of the switching means corresponding to the droplet ejection head as a droplet ejection head for which the detection of the ejection failure of the droplets is to be carried out.

11. The droplet ejection apparatus as claimed in claim 1, wherein the ejection failure detecting means detects the ejection failure of the droplets at either timing of the droplet ejection operation in a flushing process for the nozzle of the droplet ejection head selected by the ejection selecting means or timing of the droplet ejection operation during a printing operation.

12. The droplet ejection apparatus as claimed in claim 1, wherein the ejection failure detecting means includes judging means for judging presence or absence of the ejection failure of the droplets in the droplet ejection heads on the basis of the vibration pattern of the residual vibration of the diaphragm.

13. The droplet ejection apparatus as claimed in claim 12, wherein the judging means judges a cause of the ejection failure in the case where it is judged that the ejection failure of the droplets is present in the droplet ejection heads.

14. The droplet ejection apparatus as claimed in claim 13, wherein the vibration pattern of the residual vibration of the diaphragm includes a cycle of the residual vibration.

15. The droplet ejection apparatus as claimed in claim 13, wherein the judging means judges that: an air bubble has intruded into the cavity in the case where the cycle of the residual

vibration of the diaphragm is shorter than a predetermined range of cycle; the liquid in the vicinity of the nozzle has thickened due to drying in the case where the cycle of the residual vibration of the diaphragm is longer than a predetermined threshold; and paper dust is adhering in the vicinity of the outlet of the nozzle in the case where the cycle of the residual vibration of the diaphragm is longer than the predetermined range of cycle and shorter than the predetermined threshold.

16. The droplet ejection apparatus as claimed in claim 12, further comprising storage means for storing the judgment result judged by the judging means.

17. The droplet ejection apparatus as claimed in claim 1, wherein the ejection failure detecting means includes an oscillation circuit and the oscillation circuit oscillates in response to an electric capacitance component of the actuator that varies with the residual vibration of the diaphragm.

18. The droplet ejection apparatus as claimed in claim 17, wherein the ejection failure detecting means includes a resistor element connected to the actuator, and the oscillation circuit forms a CR oscillation circuit based on the electric capacitance component of the actuator and a resistance component of the resistor element.

19. The droplet ejection apparatus as claimed in claim 17, wherein the ejection failure detecting means includes an F/V converting circuit that generates a voltage waveform in response to the residual vibration of the diaphragm from a predetermined group of signals generated based on changes in an oscillation frequency of an output signal from the oscillation circuit.

20. The droplet ejection apparatus as claimed in claim 19, wherein the ejection failure detecting means includes a waveform shaping circuit that shapes the voltage waveform in response

to the residual vibration of the diaphragm generated by the F/V converting circuit into a predetermined waveform.

21. The droplet ejection apparatus as claimed in claim 20, wherein the waveform shaping circuit includes: DC component eliminating means for eliminating a direct current component from the voltage waveform of the residual vibration of the diaphragm generated by the F/V converting circuit; and a comparator that compares the voltage waveform from which the direct current component thereof has been eliminated by the DC component eliminating means with a predetermined voltage value; and

wherein the comparator generates and outputs a rectangular wave based on this voltage comparison.

22. The droplet ejection apparatus as claimed in claim 21, wherein the ejection failure detecting means includes measuring means for measuring the cycle of the residual vibration of the diaphragm based on the rectangular wave generated by the waveform shaping circuit.

23. The droplet ejection apparatus as claimed in claim 22, wherein the measuring means has a counter, and measures either a time between rising edges of the rectangular wave or a time between a rising edge and falling edge of the rectangular wave by counting pulses of a reference signal with the counter.

24. The droplet ejection apparatus as claimed in claim 1, wherein the actuator includes an electrostatic actuator.

25. The droplet ejection apparatus as claimed in claim 1, wherein the actuator includes a piezoelectric actuator having a piezoelectric element and using a piezoelectric effect of the piezoelectric element.

26. The droplet ejection apparatus as claimed in claim 1,

wherein the droplet ejection apparatus includes an ink jet printer.

27. A droplet ejection apparatus comprising:

a plurality of droplet ejection heads, each of the droplet ejection heads including an actuator, a diaphragm displaced by the actuator, a cavity filled with a liquid, and a nozzle communicated with the cavity, through which the liquid within the cavity is ejected in the form of droplets by driving the actuator, the plurality of droplet ejection heads being divided to m blocks (here, "m" is a natural number), and one of the m blocks including n droplet ejection heads (here, "n" is a natural number);

a driving circuit which drives the actuator of each of the droplet ejection heads;

a plurality of ejection failure detecting means for detecting a residual vibration of the diaphragm and detecting an ejection failure of the droplets on the basis of a vibration pattern of the detected residual vibration of the diaphragm, the number of ejection failure detecting means being the same as the number of blocks, and the plurality of ejection failure detecting means being respectively assigned to the blocks; and

recovery means for carrying out recovery processing for the droplet ejection heads to eliminate a cause of the ejection failure of the droplets, the recovery means comprising at least flushing means for carrying out a flushing process by which the droplets are preliminarily ejected through the nozzles of the droplet ejection heads by driving the actuators corresponding to the droplet ejection heads;

wherein the droplet ejection apparatus is adapted to control the flushing means to carry out the flushing processes in which a droplet is in turn ejected through the nozzle of each of the droplet ejection heads in each of the blocks n'th times to a predetermined region on which the droplets are allowed to land in order to keep up a nozzle state of each of the droplet ejection heads, and at this time each of the plurality of ejection

failure detecting means sequentially carries out the detection of the ejection failure for each of the n droplet ejection heads in the block.

28. The droplet ejection apparatus as claimed in claim 27, further comprising:

a plurality of switching means, each of the plurality of switching means switching connections of the actuators in each of the blocks from the driving circuit to the corresponding ejection failure detecting means after carrying out the droplet ejection operation by driving the actuators.

29. The droplet ejection apparatus as claimed in claim 27, further comprising judging means for judging presence or absence of the ejection failure of the droplets in the droplet ejection heads on the basis of the vibration pattern of the residual vibration of the diaphragm.

30. The droplet ejection apparatus as claimed in claim 29, wherein the judging means judges a cause of the ejection failure in the case where the judging means judges that the ejection failure of the droplets is present in the droplet ejection heads.

31. The droplet ejection apparatus as claimed in claim 30, wherein the judging means judges that: an air bubble has intruded into the cavity in the case where the cycle of the residual vibration of the diaphragm is shorter than a predetermined range of cycle; the liquid in the vicinity of the nozzle has thickened due to drying in the case where the cycle of the residual vibration of the diaphragm is longer than a predetermined threshold; and paper dust is adhering in the vicinity of the outlet of the nozzle in the case where the cycle of the residual vibration of the diaphragm is longer than the predetermined range of cycle and shorter than the predetermined threshold.

32. The droplet ejection apparatus as claimed in claim 27,

wherein the droplet ejection apparatus is adapted to periodically carry out the detection of the ejection failure by ejecting the droplets n'th times.

33. The droplet ejection apparatus as claimed in claim 27, wherein the droplet ejection apparatus is adapted to periodically carry out the detection of the ejection failure by ejecting the droplets n'th times every reciprocation of the droplet ejection heads.

34. The droplet ejection apparatus as claimed in claim 27, wherein the droplet ejection apparatus is adapted to carry out the detection of the ejection failure by ejecting the droplets n'th times immediately after the droplet ejection apparatus has been powered on.

35. The droplet ejection apparatus as claimed in claim 27, wherein the droplet ejection apparatus is adapted to periodically carry out the detection of the ejection failure by ejecting the droplets n'th times immediately after the recovery means has carried out the recovery processing.

36. A method of detecting and judging an ejection failure in droplet ejection heads of a droplet ejection apparatus, the droplet ejection apparatus including a driving circuit, a detecting circuit and a plurality of droplet ejection heads, each of the plurality of droplet ejection heads including a diaphragm, an actuator, a cavity and a nozzle, the method comprising the steps of:

selecting the nozzle of the droplet ejection head in the plurality of droplet ejection heads through which a droplet is to be ejected;

driving the actuator of the selected droplet ejection head with the driving circuit to displace the diaphragm;

carrying out a droplet ejecting operation through the nozzle;

switching a connection of the actuator from the driving circuit to the detecting circuit after carrying out the droplet ejection operation;

detecting a residual vibration of the diaphragm with the detecting circuit; and

detecting an ejection failure of the droplets on the basis of a vibration pattern of the detected residual vibration of the diaphragm.

37. The method as claimed in claim 36, wherein the droplet ejection apparatus includes a plurality of detecting circuits respectively corresponding to the plurality of droplet ejection heads; and

wherein the switching step includes switching connections of the actuators corresponding to the plurality of droplet ejection heads from the driving circuit to the detecting circuits respectively corresponding to the plurality of droplet ejection heads.

38. The method as claimed in claim 37, wherein the switching step includes switching connections of the actuators in only the selected droplet ejection heads in the selecting step from the driving circuit to the corresponding detecting circuits.

39. The method as claimed in claim 37, further comprising the step of:

specifying an arbitrary droplet ejection head in the plurality of droplet ejection heads;

wherein the switching step includes switching connections of the actuator in the specified droplet ejection head from the driving circuit to the corresponding detecting circuit.

40. The method as claimed in claim 36, wherein the ejection failure detecting step includes detecting the ejection failure of the droplets at either timing of the droplet ejection operation in a flushing process for the nozzle of the droplet

ejection head in question or timing of the droplet ejection operation during a printing operation.

41. The method as claimed in claim 36, further comprising the steps of:

judging presence or absence of the ejection failure of the droplets in the droplet ejection heads on the basis of the vibration pattern of the residual vibration of the diaphragm; and

judging a cause of the ejection failure in the case where it is judged that the ejection failure of the droplets is present in the droplet ejection heads.

42. The method as claimed in claim 36, wherein the vibration pattern of the residual vibration of the diaphragm includes a cycle of the residual vibration; and

wherein the cause judging step includes judging that: an air bubble has intruded into the cavity in the case where the cycle of the residual vibration of the diaphragm is shorter than a predetermined range of cycle; the liquid in the vicinity of the nozzle has thickened due to drying in the case where the cycle of the residual vibration of the diaphragm is longer than a predetermined threshold; and paper dust is adhering in the vicinity of the outlet of the nozzle in the case where the cycle of the residual vibration of the diaphragm is longer than the predetermined range of cycle and shorter than the predetermined threshold.

43. The method as claimed in claim 41, further comprising the step of:

storing the judgment result judged in the judging step into a storage section.